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Colour vision testing on smartphones among patients with multiple sclerosis and approach to smartphones applications in clinical practice

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Abstract

Aim: To test colour vision using Ishihara test booklet and EyeHandbook application on smartphones and compare the results of multiple sclerosis patients and healthy people. Assess approach to the use of smartphone applications in clinical practice. **Methods**: In 2015/2016 October −March a prospective study of the multiple sclerosis patients (study group) and healthy people (control group) was done by testing colour vision using 12 Ishihara booklets and the EyeHandbook application on smartphones. Both eyes were tested in controlled conditions. Correctly identified plates were counted, vision acuity tested and information about gender, age, duration of the disease and its type was collected. Also,people were interviewed on the approach to innovative technologies. Statistic analysis was done using "Microsoft Excel 2010", SPSS 20 and paired-samples t test, independent-samples t test, linear regression. p values were considered significant at $p<0.05$. **Results**: In the study group (n=44) mean score of correctly identified plates with the Ishihara booklet was 8.34±3.28 and with EyeHandbook 8.89±3.13 whereas in the control group (n=88) mean score respectively was 11.89±0.39 and 11.94±0.28, with a difference of two methods in study group t(43)=-0.55, p=0.028 and in control group t(87)=-1.68, p=0.096. Using the Ishihara booklet as the "gold standard", the sensitivity of "EyeHandbook" was 83.30% and specificity 98.00%. Older multiple sclerosis patients correctly identified less plates than younger from Ishihara booklet (coefficient -0.115, p=0.038) and EyeHandbook ($p>0.05$). Patients who have had the disease longer identified less plates from Ishihara booklet (coefficient -0.211, p=0.002) and EyeHandbook (coefficient -0.179, p=0.008). 59 (89.39%) of the respondents had a smartphone. 22 (13.90%) had downloaded medical or medical-related applications, 19 (86.36%) noticed that applications are useful in clinical practice. 55 (83.4%) said that a doctor who use the latest technologies is competent.Conclusion: Multiple sclerosis patients correctly identified more plates using EyeHandbook than the Ishihara booklet. The amount of correctly identified plates from the Ishihara booklet is associated with duration of the multiple sclerosis, there is inconsistent information if it is associated with age.The majority of ubjects use and welcome the use of smart technologies in clinical practice. **Key words**:colour vision, Ishihara, smartphone, applications, comparison.

INTRODUCTION

Multiple sclerosis (MS) is a chronic, progressive inflammatory demyelinating disease of the central nervous system[1,2].Prevalence of multiple sclerosis is from 16.7/100,00 population in Malta to 203/100,000 population in Sicily, more commonly referred to about 100-150/100,000 population [3,4,5]. Women suffer from MS two times more often than men[7]. Peak age of disease is 30-40 years ant it rarely begins before puberty or above 60 years[5]. The disease manifests with the symptoms of transverse myelitis (weakness or paralysis and sensory defects, urinary retention and loss of bowel control, spasticity and paraparesis), brain stem damage (ataxia,dysarthria, defects invision, internuclear ophthalmoplegia), cerebellar hemisphere lesions (ataxia, dysarthria, nystagmus), optic neuritis (decreased visual acuity, painful eye movements, loss of colour of vision), cerebral damage (memory loss, epilepsy, later signs of dementia occur) [5]. Optic neuritis manifests up to 50-90% of patients with MS, therefore it is very important to examine those patients for visual acuity and colour vision [8,9]. Dyschromatopsia in patiens with MS occurs more frequently(Felgueiras H, Parra J, Cruz S, Pereira P, Santos AF, Rua A et al. Dyschromatopsia in Multiple Sclerosis Patients: A Marker of Subclinical Involvement?. Journal of neuro-ophthalmology: the official journal of the North American Neuro-Ophthalmology Society, 2016). Innovative technologies changed many aspects of our lives and are applied in various spheres[10,11].There are a lot of medicine-related applications which include: treatment guidelines, measures of respiratory rate and heart rate, methods to track arterial blood pressure (all information becomes available to the family physician), as well as overviews of the diseases, illustrations and many more[12,13,14]. Many applications are designed for ophthalmologists or anyone who is interested in eye diseases [15]. iPhone® and Android® smartphones provide many diagnostic testing applications including EyeHandbook.This application contains information about various eye diseases and occurring symptoms, it allows to assess visual functions using various tests, including the colour vision test by Ishihara booklet[16]. Doctors who do not have an Ishihara booklet can use a free application and assess the patient's condition. In this study, we tested colour vision with the standard Ishihara booklet and smartphone EyeHandbook application among the study and control groups. Also we estimated approach to the use of smartphones applications in clinical practice.

METHODS

We performed a prospective study of patients in 2015/2016 October-March. The study was conducted according to the Declaration of Helsinki, the European Guidelines on Good Clinical Practice, and relevant national and regional authority requirements and ethics committees. A study group was made of 22 MS patients in remission from union of Kaunas district Oremus multiple sclerosis patients and Vilnius Low Vision center. 44 healthy people, having no known diseases causing colour vision deficiency were investigated as a control group at the Hospital of Lithuanian University of Health Sciences Kauno Klinikos Department of Ophthalmology and Vilnius University Hospital Santariškių Klinikos Center of Eye Diseases. Written informed consent was obtained from all subjects. In both groups visual acuity was tested with Snellen's chart. A colour vision test was performed in both groups using Ishihara test booklet with 12 plates and with 12 electronic versions of Ishihara booklet via the EyeHandbook application downloaded to smartphones iPhone5 and LG L9P470. Ishihara booklet on EyeHandbook application has 16 plates: 12 contain a number, 4 contain wiggly lines. Evaluated were only plates with numbers performing electronic test and plates with same numbers on non electronic Ishihara test booklet. Application was selected because at that time it was the most

comprehensive and up-to-date ophthalmology app available for iPhone and Android17 and it was free. Both eyes were investigated under equal conditions: under a standardized background illuminance, randomized by order of testing and phone model, displayed 30 cm distance from the patient. Plate was assessed as correctly answered if the subject properly identified the number on the plate, if mistaken, assessed as 0 points. The colour vision test was noted as false when 2 and more plates were identified incorrectly. We used a questionnaire to collect data such as gender, age, duration of the disease, type of MS. Subjects were interviewed on the approach to innovative technologies and various applications in everyday life as well as in clinical practice. Collected data was analyzed using "Microsoft Excel 2010" and SPSS 20. Descriptive statistics was used for gender, age, duration of disease, types of MS. The paired t-test was used to compare research methods (Ishihara booklet and EyeHandbook application), the independent samples t-test was used to compare results between women and men with MS and healthy individuals. The linear regression was performed to determine the relationship between the number of correctly identified plates and disease duration. Cross-tabs analysis was used to evaluate the sensitivity and specificity of electronic and Ishihara tests, results were compared among these tests. All p values were two tailed and they were considered significant at $p < 0.05$.

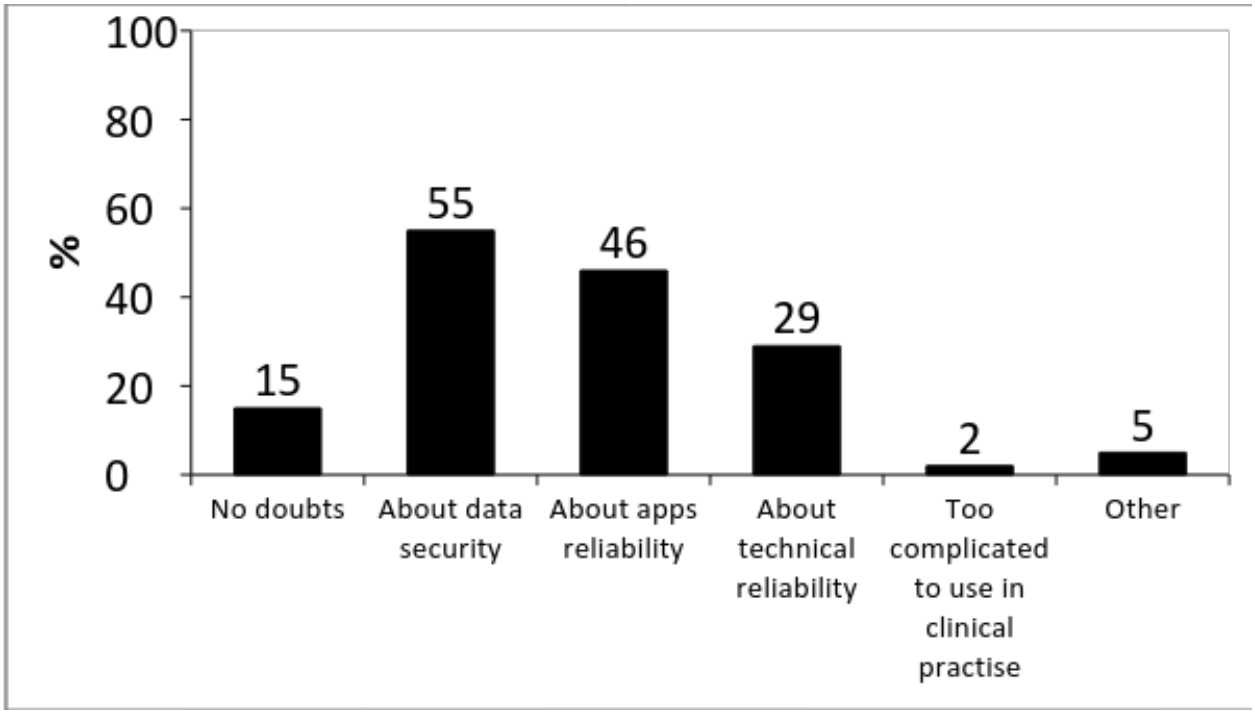
RESULTS:

67 participants were examined, 1 subject from the control group was excluded based on prespecified criteria (colour blindness). In the study group were 15 (68.18%) females and 7 (31.82%) males, in the control group: 26 (59.09%) females and 18 (40.91%) males. Average age in study group (normal distribution) was 44.59 ± 9.04 years, in control group (non-normal distribution) median age was 24 years, range 22-58 years. Both of these groups have adequate corrected visual acuity (noted in decimal). Study group OD: 0.69 ± 0.33, OS: 0.64 ± 0.40; control group OD: 0.96±0.30, OS: 0.95±0.32. The median duration of the disease among MS patients (non normal distribution) was 13.50 years, range 1-25 3years. 21 (95.45%) patients had relapsing-remitting MS type, 1 (4.55%) - secondary progressive. MS patients correctly identified less plates than healthy people testing with both methods ($p<0.001$). Both groups correctly identified more plates testing with EyeHandbook app than the booklet. In the study group difference between testing using Ishihara booklet and application colour vision test using paired t test was $t(43)=-0.55$, $p=0.028$ (95% CI). In the control group difference was $t(87)=-1.68$, $p=0.096$ (95% CI). Using Ishihara booklet as the "gold standard" for colour vision test, the sensitivity of EyeHandbook was 83.30% and specificity 98.00%. Gender was not a statistically significant factor in both groups to identify correctly Ishihara booklet and EyeHandbook plates (independent samples t-test, $p>0.05$). Among study and control groups the dependence of correctly identified number of plates on a person's age and duration of disease were evaluated with linear regression analysis. Overall older people correctly identified less plates than younger. The quantity of correctly answered plates in study group was associated with age when the test was performed with Ishihara booklet ($p=0.038$), but not with EyeHandbook ($p>0.05$). Age was not a statistically significant factor in the control group to identify correctly Ishihara booklet and EyeHandbook plates ($p>0.05$). The quantity of correctly answered plates in the study group was associated with the duration of the disease when the test was performed with the Ishihara booklet ($p=0.002$) and EyeHandbook ($p=0.008$).59 (89.39%) of the respondents had a smartphone. 22 (13.90%) had downloaded a medical or medical-related application, 19 (86.36%) noticed that applications are useful in clinical practice. 26 (39.4%) indicated that use of innovative technologies has a positive impact on the doctor-patient relationship, 11 (16.7%) noted − negative, 29 (43.9%) − no effect **(Table 1) (Fig. 1).**

Table 1. Questionnaire.

	Every time	Rarely	Never
How often do you see a doctor using a smartphone in clinical practise?	7 (10.61%)	33 (50.00%)	26 (39.39%)
How often do you see a doctor using a smartphone next to the patient	2 (3.03%)	18 (27.27%)	46 (69.70%)
	Yes	No	Don‘t know
Would you agree to a doctor saving your information on smartphone?	39 (59.09%)	16 (24.24%)	11 (16.67%)
Would you like that a doctor explain about your disease using smartphones?	47 (71.21%)	10 (15.15%)	9 (13.64%)
Does your doctor use a smartphone while doing your examination?	3 (4.55%)	53 (80.30%)	10 (15.15%)
Do you think that a doctor using innovative technologies is competent?	55 (83.33%)	2 (3.03%)	9 (13.64%)

Figure 1. Doubts about using smartphones/innovative technology in clinical practise.



DISCUSSION

A total of 67 participants 66 were taken up for the present research. The study group patients 15 (68.18%) females and 7 (31.82%) males had MS diagnosis. Their average age of disease onset were 30-50 years of age (63.64%) which coincides with literature data. The most common MS type is relapsing-remitting (85%) [7], it was also the main type among our subjects (95.45%). Although there was only 1 (4.55%) case of secondary progressive MS type, it is stated that after 10-15 years of MS, 50-60% of patients have this type[7]. Visual acuity for participants was tested to assess whether a person is able to see a colour plate due to central vision disorders. Further colour vision tests were carried out because visual acuity was sufficient, however MS patients frequently has visual problems which can influence the results. Also it should be noted, that the changes in screen brightness can affect the performance of the test. T. Emborgoet al. study showed that more plates were correctly identified testing with the EyeHandbook application than the Ishihara booklet and this is statistically significant in the study group, but not in the control group [18], this coincides with our study. Also our study group patients correctly identified less plates than in the study mentioned previously. It may be because it is unknown what visual impairments Emborgo et al study participants had, or even if they all had colour vision related disorders. Comparison of the sensitivity and specificity is complicated by the lack of information about correctly identified plates evaluation criteria (in our study pathological colour vision was assigned when participant incorrectly identified 2 and more plates), this might be affected by sample size (Table 2). A similar study was done comparing colour vision among healthy and colour-deficient subjects using applications Eye2Phone and Colour Vision Test on smartphones and Ishihara. There was no statistically significant difference between Eye2Phone and Ishihara booklet, but the Colour Vision Test was significantly different than both other tests. Colour-deficient subjects correctly identified more plates using Ishihara booklet than Eye2Phone app[19]. This result contradicts our study because our subjects identified more plates using application than booklet. Recent study done in UK showed that over 90% doctors have a smartphone and 54% medical applications. Almost 80% stated that they would be willing to use their smartphone for clinical use and there was no significant difference between junior and senior clinicians regarding this ($p>0,05$) [20]. 85% residents and almost 50% faculty claimed using smartphones during rounds for patient carebut said it can also be distracting [21].

Table 2. Comparison between T.Emborgo study and this study.

	T . Emborgo study (11)	Study in Vilnius and Kaunas
Study group (eyes)	113	44
Control group (eyes)	80	88
Ishihara booklet in study group	10.08±2.11	8.34±3.28
EyeHandbook in study group	10.29±2.07	8.89±3.13
Ishihara booklet in control group	10.91±0.28	11.89±0.39
EyeHandbook in control group	10.94±0.29	11.94±0.28
Sensitivity	89.00%	83.30%
Specificity	99.00%	98.00%

MS patients correctly identified more plates when a colour vision test was carried out with the EyeHandbook application than with the Ishihara booklet. The amount correctly identified with the Ishihara booklet is associated with duration of the multiple sclerosis, there is inconsistent information if it is associated with age. Diagnostic application on smartphone or tablet is simple to use, also it is a free and prompt alternative to expensive paper Ishihara test booklet. The majority of subjects use and welcome the use of smart technologies in clinical practice, nearly half believe that it should not affect doctor and patient relationship. There is minimal evidence to support the validity of these non-standardized smartphone applications. Also there is lack of standardized evaluation rules, for example the application consists of less plates than a standard Ishihara booklet. It would be appropriate to investigate whether other applications for colour vision assessment are more effective than EyeHandbook and estimate their applicability in patients with other diseases that might cause colour vision disord

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